IV.A.2.f RUTGERS COMPUTERS IN BIOMEDICINE

Rutgers Research Resource
Computers in Biomedicine

Dr. Saul Amarel
Rutgers University
New Brunswick, New Jersey

(Grant NIH RR-00643-05, 3 years, $314,880 this year)

I. PROJECT GOALS AND APPROACHES

The fundamental objective of the Rutgers Resource is to develop a computer based framework for significant research in the biomedical sciences and for the application of research results to the solution of important problems in health care. The focal concept is to introduce advanced methods of computer science - particularly in artificial intelligence - into specific areas of biomedical inquiry. The computer is used as an integral part of the inquiry process, both for the development and organization of knowledge in a domain and for its utilization in problem solving and in processes of experimentation and theory formation.

The Resource community includes 46 researchers - 26 members, 8 associates and 12 collaborators. Members are mainly located at Rutgers. Collaborators are located in several distant sites and they interact - via SUMEX-AIM - with Resource members on a variety of projects, ranging from system design/improvement to clinical data gathering and system testing. At present, collaborators are located at the Mt. Sinai School of Medicine, N.Y.; Washington University School of Medicine, St. Louis, Mo.; Johns Hopkins Medical Center, Baltimore, Md.; Illinois Eye and Ear Infirmary, Chicago, Ill.; College of Medicine and Dentistry of New Jersey (CMDNJ); and the University of Miami.

Research in the Rutgers Resource is oriented to "discipline-oriented" projects in medicine and psychology, and to "core" projects in computer science, that are closely coupled with the "discipline-oriented" studies. Work in the Resource is organized in three AREAS OF STUDY; in each area ther are several projects. The areas of study and the senior investigators in each of them are:

(1) Medical Modeling and Decision Making (C. Kulikowski, A. Safir).

(2) Modeling Belief Systems (C. F. Schmidt, N. S. Sridharan).

(3) Representations, Modeling and Hypothesis Formation in AI (S. Amarel).

In addition the Rutgers Resource is sponsoring an Annual National AIM Workshop, whose main objective is to strengthen interactions between AIM activities, to disseminate research methodologies and results, and to stimulate collaborations and imaginative resource sharing within the framework of AIM. The first AIM Workshop was held at Rutgers on June 14 to 17, 1975. The Second Workshop is scheduled for June 1 to 4, 1976.

II. AREAS OF STUDY; SUMMARY OF GOALS AND ACTIVITIES

(1) Medical Modeling and Decision-Making

Present projects include:

(i) Development and clinical testing of the glaucoma consultation program based on a causal-associational network (CASNET) model - as a collaborative project of the ophthalmological network, which has grown in the last year to include: Mt. Sinai School of Medicine, Washington University, Johns Hopkins University, University of Illinois at Chicago, and the University of Miami.

(ii) Investigation of descriptive models of diseases based on a general semantic network representation, with associated strategies of diagnosis, prognosis, and therapy. These models subsume a variety of sub-models useful in general consultation. A particular emphasis is placed on the analysis of the time course of disease, and inter-relationships between various disease sub-processes.

(iii) Development of a data base for clinical research associated with the consultation programs. The results of the data analyses to be used selectively in updating and improving the models of diseases.

(iv) Investigation of various techniques for acquiring knowledge from clinical experts. Incorporation of alternative expert opinions within a model.

(v) In collaboration with the Mt. Sinai Rutgers Health Care Computer Laboratory, we are developing models for refraction and neuro-ophthalmology.

The following is a summary of accomplishments in this area.

(a) The ophthalmological network(ONET) is actively underway, with consultation programs available through SUMEX-AIM to the five collaborating institutions.

(b) The consultation system has been perfected by adding many details of diagnosis, prognosis, and therapy; new observations and decision criteria have been specified as the result of suggestions by the ONET collaborators.

(c) A data base for storing cases and providing a chronological model based interpretation has been created.

(d) A set of programs to analyze the case histories has been developed. They are currently being used in collaborative clinical studies by ONET members. Selected results are to be incorporated into the glaucoma model.

(e) A semantic network based model for glaucoma has been implemented with expanded capabilities for explanation and a greater facility for being updated.

The progress in extending the collaborative activities of the ophthalmological network has been made possible by the facilities and support provided by SUMEX-AIM. The semantic network model is being developed on INTERLISP at SUMEX-AIM. Other program development activities are evenly distributed between SUMEX-AIM and the Rutgers-10.

(2) Modeling Belief Systems

The overall goal of this project is to develop a computer based psychological model of how persons reason about the causes of human action. The common-sense notion of social causation which is used to understand intentional actions has served as the focus of this effort The construction of a system (called BELIEVER) to assist in the description of the psychological theory and to facilitate the testing of the theory is a principal goal of this project and to date we have accomplished the following:

(a) A working system has been developed that accepts the descriptions of Templates, Relations and their consistency conditions which are concepts developed in the Meta Description System (MDS) framework.

(b) We have described PLANS, ACTS, PERSONS and SUMMARIES as templates; we have defined the consistency conditions associated with the relations among these.

(c) Developed procedures in FUZZY for Instantiating Act Descriptions and calculating presuppositions needed to form coherent interpretations.

(d) We have provided for an easy-to-understand prompting scheme based on the concept of templates and consistency conditions. The prompting proceeds using the template descriptions and attempts to fill in missing information by implication following based on the consistency conditions.

(e) Developed a framework for submitting and analyzing the semantics of experimental evidence when the subject responses are solely unstructured natural language text.

Our goals for the immediate future are:

(a) To continue to gather experimental data and follow the analysis to suggest hypothesis in the Believer Theory.

(b) Develop strategy Plan Recognition based on a Theory of Motivation and Consistency postulates of a Persons beliefs and knowledge.

(c) Continue to investigate the innovative uses of our descriptive methodology in empirical procedures.

The development of MDS - which provides a framework for designing the BELIEVER system - was carried out at SUMEX-AIM until October 1975; subsequently, most of the work on MDS was shifted to ISID. While early versions of BELIEVER were developed at SUMEX-AIM, the last year saw a shift in computing on this project from SUMEX-AIM to the Rutgers-10 - since program development is being done on the FUZZY system which runs on the Rutgers computer.

(3) Representations, Modeling and Hypothesis Formation in Artificial Intelligence

A major part of our effort in this area is oriented to collaborations with investigators in other Resource projects - involving applications of AI ideas and programs and also identification and initial exploration of new significant AI problems. The collaboration in the BELIEVER area has lead to a close integration of the basic AI oriented work (N. S. Sridharan) and the discipline oriented work (C. Schmidt) in the area. This work is reported under 2 above.

"Core" projects in the present area include:

(i) Development and applications of FUZZY (R. LeFaivre). The FUZZY system was transferred from UNIVAC 1110 LISP to UCI LISP on the Rutgers-10. A number of improvements were made, both to the UCI LISP system and to the FUZZY language to make it both more efficient and more powerful. These changes include a new prettyprint package for UCI LISP and functions for computing differences of associative nets and creating multiple contexts in FUZZY. FUZZY is currently being used in the initial implementation phase of the BELIEVER system. Applications to reasoning in medical diagnosis are being explored.

(ii) Applications of grammatical inference schemes to automatic adjustment of medical models on the basis of clinical data (A. Walker).

(a) An algorithm was found to eliminate loops from stochastic causal models.

(b) A grammar model for the flow of control in programs was formulated.

(c) A technique for progressively bounding a search space of stochastic grammars, in terms of grammars already found, was studied theoretically and tested in practice.

(d) The impact of this work on the automated construction of production-rule based AI systems is now under study.

Computing in this project is done on the Rutgers-10.

(iii) Development of a grammatical inference system using a "developmental paradigm" (W. Fabens). This is a hypothesis formation system which attempts to change a given context free grammar so as to accommodate new sentences that cannot be derived from the given grammar. The system includes (a) a relaxation parser - which comes as close as it can to an interpretation of a given "deviant sentence", (b) a rule hypothesizer which uses such an interpretation to propose changes to the current grammar, (c) a rule coalescer which summarizes with as little loss or gain in generality as possible the newly hypothesized grammar. We have developed programs in all of these areas and are currently composing them into a single system. Computing in this project is done on the Rutgers-10.

(iv) Development and study of systems for theory formation in programming tasks (S. Amarel). A system is being developed for acquiring knowledge about a program formation task. The system involves the generation, management and evaluation of programs at various stages of specification. In this project, major emphasis is given to problems of representation and to the effect of shifts between representations. Program development is being done on the Rutgers-10.

While the first project discussed in this area is focusing on the development of AI languages that can provide a stronger basis for system development in the Resource, the last three projects are focusing on different AI approaches to hypothesis (theory) formation - an area which is essential to the automatic acquisition and improvement of a knowledge base from experimental data.

III. AIM WORKSHOP

The first annual AIM Workshop was held June 14-17, 1975. The first day was devoted to a General Session to provide an overview of current AIM activities and a broad forum for discussion. The following three days were devoted to discussions in depth of AIM designs, and to demonstrations of current systems. Several AIM systems were effectively demonstrated on SUMEX during the Workshop.

The second annual AIM Workshop will be held June 1-4, 1976. The entire four days will be devoted to lectures and panel discussions on current projects in the AIM community, and on problems of knowledge representation, reasoning, and AI system design. Papers on language, speech, vision, education and problem solving will summarize recent AI approaches, while the role of biomathematical modeling and inference methods will be the focus of summary papers and panel discussions. Tutorials on languages and systems available to the AIM community will also be presented. The Workshop will conclude with a panel on the dissemination of scientific information and computer networking.

The SUMEX-AIM system is essential for the Workshop. Many of the AIM programs will be running on SUMEX-AIM and accessed via TYMNET or ARPANET from Rutgers. The message facilities of SUMEX-AIM are most useful for planning, communicating and setting up the information pool for the AIM Workshop.

IV. INTERACTIONS WITH THE SUMEX-AIM RESOURCE

During the past year we have continued to use the SUMEX-AIM resource for program development and testing, for communications between collaborators distributed in different parts of the country and for preparation and running of the AIM Workshop.

Computing in the Rutgers Research Resource is distributed between SUMEX-AIM and the Rutgers-10. The relative utilization of SUMEX-AIM by "local" Rutgers users has decreased this year. The utilization of SUMEX-AIM by our "remote" medical collaborators has been growing. The total amount of computing at SUMEX by our Resource users and by our collaborators has decreased relative to the previous year. One of the reasons for this was the overloaded condition of SUMEX-AIM. Another important related problem was the relatively poor quality of communication facilities available to us via TYMNET.

In order to provide a more reliable and convenient network environment for our investigators and their collaborators and also for the AIM Workshop, we have proceeded this year with the implementation of several enhancements to the Rutgers-10. These enhancements were planned in consultation with AIM management, with the intention of bringing to the AIM network complementary facilities and added capacity. Two stages of enhancement have been completed this year: (a) core memory and fixed head disk were augmented and the TOPS 6.02 operating system was installed; (b) a TYMCOM communications unit was installed, making the Rutgers-10 accessible via TYMNET - in time for support of the second AIM workshop.

The SUMEX-AIM facility played a key role this year in consolidating our network of collaborators in ophthalmology (ONET) and providing the support needed for establishing a productive collaboration among the ONET investigators.

The SUMEX staff have continued to function as models of excellent cooperation. They have been very helpful and responsive in sharing information and keeping us aware of developments, problems, new ideas, etc. SUMEX continues to be a good forum for communicating, linking and talking with various investigators in our Resource as well as with others in the AIM community.

The AIM Workshops rely heavily on SUMEX-AIM. In the first Workshop, the demo sessions and the hands-on activities with remote systems were found to be very effective in disseminating AIM methods and techniques to a broad group of participants. The significant role played in these demos by the SUMEX staff, and by the SUMEX resource, cannot be overstated. In our planning for the second AIM Workshop we are also placing strong emphasis on on-line activities, more so considering the broader class of participants who will meet this year.

SUMEX-AIM has been most useful in communicating, planning and helping to set up the information pool for this AIM Workshop.

In conclusion, the SUMEX-AIM facility is continuing to be an essential part of our research environment. In view of our AIM Workshop activities and the related enhancement of the Rutgers-10, we are moving to a point where the interactions between the Rutgers project and SUMEX-AIM are increasing in scope - as Rutgers is gradually adding to its "user" role a "server" role for the national AIM project.

IV. LIST OF PROJECT PUBLICATIONS

[1] Amarel, S., and Kulikowski, C. (1972) "Medical Decision Making and Computer modeling, Proc. of 5th International Conference on Systems Science, Honolulu, January 1972.

[2] Amarel, S. (1974) "Computer-Based Modeling and Interpretation in Medicine and Psychology: The Rutgers Research Resource", Proc. on "Conference on the Computer as a Research Tool in the Life Sciences", June 1974, Aspen, by FASEB; also appears as Computers in Biomedicine TR-29. June 1974, Rutgers University.

[3] Amarel, S. (1974) "Inference of Programs from Sample Computations", Proc. of NATO Advanced Study Institute on Computer Oriented Learning Processes, 1974, Bonas, France.

[4] Bruce, B., (1972) "A Model for Temporal Reference and its Application in a Question Answering Program", in "Artificial Intelligence", Vol. 3, Spring 1972.

[5] Bruce, B. (1973) "A Logic for Unknown Outcomes", Notre Dame Journal of Formal Logic; also appears as Computers in Biomedicine, TM-35, Nov. 1973, Rutgers University.

[6] Bruce, B. (1973) "Case Structure Systems", Proc. 3rd International Joint Conference on Artificial Intelligence (IFCAI), August 1973.

[7] Bruce, B. (1975) "Belief Systems and Language Understanding", Current Trends in the Language Sciences, Sedelow and Sedelow (eds.) Houton, in press.

[8] Chokhani, S. and Kulikowski, C.A. (1973) "Process Control Model for the Regulation of Intraocular Pressure and Glaucoma", Proc. IEEE Systems, Man & Cybernetics Conf., Boston, November 1973.

[9] Chokhani, S. (1975) "On the Interpretation of Biomathematical Models Within a Class of Decision-Making Procedures", Ph.D. Thesis, Rutgers University; also Computers in Biomedicine TR-43, May, 1973.

[10] Fabens, W. (1972) "PEDAGLOT. A Teaching Learning System for Programming Language", Proc. ACM Sigplan Symposium on Pedagogic Languages, January 1972.

[11] Kulikowski, C.A. and Weiss, S. (1972) "Strategies for Data Base Utilization in Sequential Pattern Recognition", Proc. IEEE Conf. on Decision and Control, Symp. on Adaptive Processes, December 1972.

[12] Kulikowski, C.A. and Weiss, S. (1973) "An Interactive Facility for the Inferential Modeling of Disease", Proc. 7th Annual Princeton Conf. on Information Sciences and Systems, March 1973.

[13] Kulikowski, C.A. (1973) "Theory Formation in Medicine: A Network Structure for Inference", Proc. International Conference on Systems Science, January 1973.

[14] Kulikowski, C.A., Weiss, S., and Safir, A. (1973) "Glaucoma Diagnosis and Therapy by Computer", Proc. Annual Meeting of the Association for Research in Vision and Ophthalmology, May 1973.

[15] Kulikowski, C.A. (1973), "Medical Decision-Making and the Modeling of Disease", Proc. First Intern. Conf. on Pattern Recognition, October, 1973.

[16] Kulikowski, C.A. (1974) "Computer-Based Medical Consultation"-- A Representation of Treatment Strategies", Proc. Hawaii International Conf. on Systems Science, Jan. 1974.

[17] Kulikowski, C.A. (1974) "A System for Computer-Based Medical Consultation", Proc. National Computer Conference, Chicago, May 1974.

[18] Kulikowski, C.A. and Safir, A. (1975) "Computer-Based Systems Vision Care", Proceedings IEEE Intercon, April 1975.

[19] Kulikowski, C. and Trigoboff, M. (1975a) "A Multiple Hypothesis Selection System for Medical Decision-Making", Proc. 8th Hawaii International Conference on Systems Sciences, January 1975.

[20] Kulikowski, C. & N.S. Sridharan, "Report on the First Annual AIM Workshop on Artificial Intelligence in Medicine. Sigart Newsletter No. 55, December 1975.

[21] Kulikowski, C., "Computer-Based Consultation Systems as a Teaching Tool in Higher Education, 3rd Annual N.J. Conference on the use of Computers in Higher Education, March 1976.

[22] Kulikowski, C., Weiss S., Safir, A. et al "Glaucoma Diagnosis & Therapy by Computer: A Collaborative Network Approach" Proc. of ARVO, April 1976.

[23] Kulikowski, C., Weiss, S., Trigoboff, M. Safir, A., "Clinical Consultation and the Representation of Disease Processes", Some AI Approaches, AISB Conference, Edinburgh, July 1976.

[24] LeFaivre, R., "Procedural Representation in a Fuzzy Problem-Solving System", Proc. Natl. Computer Conf., New York, June 1966

[25] LeFaivre, R. and Walker, A. "Rutgers Research Resource on Computers in Biomedicine, H", Sigart Newsletter No. 54, October 1975.

[26] Mauriello, D. (1974) "Simulation of Interaction Between Populations in Freshwater Phytoplankton", Ph.D. Thesis, Rutgers University, 1974.

[27] Schmidt, C. (1972) "A comparison of source unidimensional, multidimensional and set theoretic models for the prediction of judgements of trail implication", Proc. Eastern Psych. Assoc. Meeting, Boston, April 1972.

[28] Schmidt, C.F. and D'Addamio, J. (1973) "A Model of the Common Sense Theory of Intension and Personal Causation", Proc. of the 3rd IJCAI, August 1973.

[29] Schmidt, C.F. and Sedlak, A. (1973) "An Understanding of Social Episodes", Proc. of Symposium on Social Understanding in Children and Adults: Perspectives in Social Cognition, American Psych. Assoc. Convention, Montreal, August 1973.

[30] Schmidt, C.F., Sridharan, N.S., & Goodson, J.L. Recognizing plans and summarizing actions. Proceedings of the Artificial Intelligence and Simulation of Behavior Conference, University of Edinburgh, Scotland. July 1976.

[31] Schmidt, C. Understanding human action: Recognizing the plans and motives of other persons. In (eds. J. Carroll and J. Payne) Cognition and Social Behavior. Potomac, Maryland:

[32] Schmidt, C.F. (1975) "Understanding Human Action", Proc. Theoretical Issues in Natural Language Processing: An Interdisciplinary Workshop in Computational Linguistics, Psychology, Artificial Intelligence, Cambridge, Mass., June 1975. Also appears as Computers in Biomedicine, TM-47, June 1975, Rutgers University.

[33] Schmidt, C.F. (1975) "Understanding Human Action: Recognizing the Motives", Cognition and Social Behavior, J.S. Carroll and J. Payne (eds.), New York: Lawrence Earlbaum Associates, in press. Also appears as Computers in Biomedicine, TR-45, June 1975, Rutgers University.

[34] Sedlak, A.J. (1974) "An Investigation of the Development of the Child's Understanding and Evaluation of the Actions of Others", Ph.D. Thesis, Rutgers University

[35] Sridharan, N.S., "The Frame and Focus Problems in AI: Discussion in relation to the BELIEVER System. Proceedings of the Conference on Artificial Intelligence & the Simulation of Human Behavior, Edinburgh, July 1976.

[36] Srinivasan, C.V. (1973) "The Architecture of a Coherent Information System: A General Problem Solving System", Proc. of the 3rd IJCAI, August 1973.

[37] Tucker, S.S. (1974) "Cobalt Kinetics in Aquatic Microcosms", Ph.D. Thesis, Rutgers University.

[38] Vichnevetsky, R. (1973) "Physical Criteria in the Evaluation of Computer Methods for Partial Differential Equations", Proc. 7th International AICA Congress, Prague, Sept. 1973; reprinted in Proc. of AICA, Vol. XVI, No. 1, Jan. 1974, European Academic Press, Brussels, Belgium.

[39] Vichnevetsky, R., Tu, K.W., Steen, J.A. (1974), "Quantitative Error Analysis of Numerical Methods for Partial Differential Equations", Proc. Eighth Annual Princeton Conference on Information Science and Systems, Princeton University, March 1974.

[40] Weiss, S. (1974) "A System for Model-Based Computer-Aided Diagnosis and Therapy", Parts I and II, Ph.D. Thesis, Rutgers University; also Computers in Biomedicine TR-27, Feb. 1974.

IV.B INFORMAL PROJECTS

The following is a summary of the various "pilot" projects which have been admitted to SUMEX on a temporary basis pending development of a formal proposal. Many of these projects reflect initial efforts at formalizing analyses of experimental situations in preparation for the development of DENDRAL-like heuristic inference generation and modeling.

IV.B.1 STANFORD PILOT PROJECTS

IV.B.1.a AI IN MOLECULAR GENETICS - MOLGEN

THE MOLGEN SYSTEM FOR EXPERIMENTAL MOLECULAR GENETICS

Prof. J. Lederberg
Stanford Department of Genetics

The MOLGEN system is designed to aid the experimental molecular geneticist in many important phases of laboratory investigation. It will be composed of three major interacting parts: an experiment planning system, an enzymatic action simulation program, and a collection of knowledge bases containing the rules and heuristics of molecular genetics.

The experiment planning program will collect information about a problem from the user, select an appropriate methodology for solution (information retrieval, simulation, hierarchical planning, or some combination thereof) and then work interactively with him to solve the problem. Some examples of the range of problems MOLGEN's experiment planner will deal with are:

1. The user wishes to know which enzymes will function under a given pH or salt concentration--a straight information retrieval problem.

2. The user wants an accurate prediction of the ratio of linear to circular DNA after application of ligase to a given starting concentration of "sticky-ended" DNA--a problem best handled by a discrete simulation.

3. The user wants a verification that a proposed experiment will produce something like a desired result--probably a combination of retrieval and simulation.

4. The user wants a plan to synthesize and then analyze a new DNA structure--a deep problem involving hierarchical planning methods making full use of all program facilities.

The simulation program will provide detailed modeling of the action of enzymes on nucleic acid structures. The program has been shown to produce accurate and reproducible results on several diverse structures for simple ligation, and is being extended to other common enzymatic actions (exo and endo-nucleases, polymerase, etc.).

The knowledge bases will be composed of collections of the rules and heuristics used by geneticists, as well as facts about enzymes, experimental methods, and physical processes like de/renaturation. They will be designed to allow access in retrieval, simulation, and planning modes, so the major problem lies in represen-tation of diverse types of knowledge in a common, consistent fashion.

Along with the major system components discussed above, certain themes remain dominant in all phases of system design. Primary consideration is given to making the system an easy and natural tool for the molecular geneticist to use. Nucleic acid structure entry, editing, and display is by way of an interactive, user-oriented program. Explanation facilities (in the manner of the MYCIN system) will be provided whenever possible, and all knowledge bases made easily extendable and modifiable. We consider the trust and cooperation of the expert user vital to continued system development, and consider the best way to provide for this cooperation is to make the system immediately useful and intelligible to geneticists.

IV.B.1.b BAYLOR-METHODIST CEREBROVASCULAR PROJECT

BAYLOR-METHODIST CENTER FOR CEREBROVASCULAR RESEARCH
DATA SERVICES RESEARCH LABORATORY

John L. Gedye, M.D.
Department of Neurology
Baylor College of Medicine
Houston, Texas

During the year the data services research laboratory has had a total of about 3,000 hours of man-effort available, of which about 50% has been devoted to implementation of the local facilities described below, and a further 5% has been devoted to the SUMEX pilot study.

A) GENERAL GOALS

Clinical research in neurology, as exemplified by the program of the Baylor-Methodist Center for Cerebrovascular Research, creates a large number of data handling problems of a wide variety of types. The Data Services Research Laboratory seeks to support the program of the center by developing and making available a comprehensive range of data acquisition storage, processing and display techniques for the center's investigative laboratories. These techniques are being designed to facilitate the systematic study of inter-relationships between the different types of data gathered from the various cerebrovascular disease patient groups being studied by the center.

Technical Resources

At the beginning of last December the Data Services Research Laboratory accepted delivery of a Digital Equipment Corporation (DEC) PDP-11/35 computer configuration with 32K core, 2 RK05 disks, a TS03 magnetic tape unit, a Terminet 1200 printer acting as console and hard-copy device, and 2 modified Hazeltine 1200 video display terminals for general interactive use. the system has incoming (1) and outgoing (1) 300 baud modem interfaces to the public switched network the latter incorporating a Bell 801C autodialler. This configuration supports time-shared services, both interactive and batch, based on a single user-language (this is an extended basic called BASYS - the system is currently operating under the commercially supported version of BASYS V3P, known as AIMS V3P - for details see the latest edition of the AIMS-11 programming manual, November 1975, obtainable from ARBAT Systems Limited, 61 Broadway, New York, N.Y. 10006).

Access to SUMEX

This has been by means of TYMNET, which we access through one of the Houston TYMSAT's. At the beginning of the project we used a 300 baud TI

Silent 700 terminal in the normal manner, but since the installation of our local PDP-11/35 configuration in December, we have taken advantage of our autodial facilities and the supporting facilities provided in BASYS V3P and have used our BAYSYS terminals for this purpose. As a result of this experience we are now considering implementing software which will allow an easier interface between our local system and the resources of SUMEX. We have in mind an ability to create files on our system and pass them to SUMEX and to pick up files from SUMEX and store them locally. It is felt that implementing such facilities will greatly facilitate interaction with the SUMEX resource and will lead naturally to the procedures needed to support our AI research.

B) MEDICAL RELEVANCE

The system designed and implemented for the Center for Cerebrovascular Research (BAYSYS - not to be confused with BASYS) allows:

1) Maintenance of an immediately accessible, up-to-date, cross-referenced directory of all patients who have, at any time, come under the care or investigation of members of the clinical staff of the Department of Neurology, together with a record for each showing what data has been gathered and where it is located. On March 31, 1976 the directory contained 570 entries, and experience to date suggests that in order to keep up with the patient throughput of the center, new names will be added at a rate of about 100/month. As presently configured the system has a directory capacity of 6,000.

2) Storage in a readily accessible, computer-compatible form, of all data gathered on patients which may be relevant to the current and future research interests of the center. Investigatory data is regularly archived on industry compatible magnetic tape in a format which allows subsequent collation using standard sort and merge software.

The work of the Data Services Research Laboratory is organised around the assumption that the research activities of the center can, for all practical purpose, be regarded as a set of inter-related projects, each of which includes planned data acquisition by one or more of the investigative laboratories of the center in accordance with a predetermined schedule.

As a result of providing these primary data gathering services to the investigatory laboratories of the center, the Data Services Research Laboratory will acquire access to a reliable data base covering in principle, the entire range of activities of the center, and this will allow a range of secondary data handling activities to be undertaken on behalf of the center.

It appears that the main technical problem that will have to be solved before it is possible to keep up with the potential flow of data is the design and implementation of a suitable range of data input procedures to cope with the wide variety of data types. It is hoped that the new hand held OCR wand recently developed by Recognition Equipment, Inc. of

Dallas, Texas will allow us to develop a suitably flexible data entry work station for our purposes.

C) PILOT STUDY

The aim of this study has been to formulate a project relevant to the activities of the center which will provide an acceptable and legitimate "point of entry" for artificial intelligence research, and which will allow the systematic formulation of objectives for the future. We are, at the present time, focussing on situations in which a researcher working in the Center for Cerebrovascular Research is required to respond to information from a new source and in some way incorporate it into his understanding of a class of clinical situations.

Background

A continual source of background guidance for our work has been the writings of Stephen Toulmin, particularly his book "Human Understanding" (the first volume of which appeared in 1972) in which he develops a evolutionary approach to the subject in terms of a "populational" account of conceptual change in intellectual disciplines. From the standpoint of Toulmin´s approach "men demonstrate their rationality not by ordering their concepts and beliefs in tidy formal structures, but by their preparedness to respond to novel situations with open minds - acknowledging the shortcomings of their former procedures and moving beyond them". The emphasis in his approach to rationality is thus on "change", on the circumstances under which and the means by which men change their concepts and beliefs. Our work to date can be thought of as an attempt to model this approach to the growth of human knowledge in a specific situation - assimilating the results of the new 133XE inhalation regional cerebral blood flow assessment technique. The approach requires at least 3 levels of activity:

1. Choice of goals of rational enterprise

2. Development of concepts

3. Formulation of arguments

The basic approach has been to design as system which will, when provided with with a set of descriptions of paradigmatic patients representing two clinical conditions, automatically formulate an optimal algorithm (or in other words a set of decision rules which makes the best use of the available information) for discriminating between those two conditions, and which can then be used on a new set of patients for various purposes. The approach has been tested on regional cerebral blood flow data by checking an algorithm developed from a representative set of 32 patients who acted as paradigms on a similar set of 32 patients and a diagnostic success rate of 90% was obtained in relation to the request "Tell me, on the basis of regional cerebral blood flow measurements alone, whether this individual is normal or abnormal".

The approach appears to have a wide range of applications in the context of the work of the center and effort is currently being concentrated on applying the technique to the systematic exploration of regional cerebral blood flow differences in relation to such contrasts as "male/female", "left-hemisphere/right hemisphere" and so on. The technique can be applied to data as it accumulates, thus allowing the detection of trends at an early stage of the research.

It is inappropriate to go into details of the approach here, but it's essential feature is that it permits revision of both conceptual boundaries (such as what is meant by "high" as opposed to "low" flow in a particular brain region) and of arguments expressed in terms of a given set of concepts (such as: "high" flow in region x, together with "low" flow in region y, and "high" flow in region z implies multi-infarct dementia as opposed to Alzheimer's dementia) as a result of the acquisition of new data.

II) INTERACTIONS WITH THE SUMEX-AIM RESOURCE

A) Collaborations Through the Network

We have not yet reached a stage at which we are able to support regular collaboration through the network. We hope that this will develop naturally as soon as we have been able to develop interface between our local PDP-11/35 system and SUMEX so that we can handle interaction as a natural part of our day to day activities. Dr. David Bowen is planning to cooperate with us during the summer from London over ARPANET, and we intend to work together on his neurochemical data.

B) Contacts and Cross Fertilisations

The Rutgers workshop was the most valuable feature of SUMEX-AIM participation during the year, providing an opportunity to get an overview of work in progress and to see directions in which our work here could develop to complement what was being done elsewhere. On the clinical application side the "INTERNIST (DIALOG)" project was the most stimulating, as it demonstrated the challenges that would have to be met by any practically useful approach, for example: the ability to handle multiple problems presenting together.

At a more fundamental level "DENDRAL" confirmed the value of the approach to which we are committed - trying to model the research process itself. As a result of the Rutgers workshop, a working relationship has been established with Drs. Lindberg and Blackwell of the University of Missouri and there have been reciprocal visits between our respective locations. On my last visit to Columbia, I gave an invited paper called "A Jurisprudential Approach to Artificial Intelligence" and have since been invited to write this up for "Biosciences Communications".

Dr. Lindberg's work on the encipherment of electrolyte patterns has proved to be a useful stimulus to our own work on the encipherment of neurological data, and suggestions from myself that it might be valuable to look at electrolyte pattern transitions has been taken up and developed as an application of the theory of finite state machines.

C) Critique of Resource Service

Our use of the computational resources of SUMEX has so far been largely confined to experimentation with the various modules of the system described above. This was particularly valuable before our own resources became available. We now see ourselves moving to a new mode of operation in which we try to find out which things are best done on SUMEX and which locally. Our main criticism to date has been slowness of response during peak hours, when, unfortunately we have sometimes had to try to operate because of constraints on manpower availability.

FUNDING STATUS

Work is currently being supported by departmental funds. However, we have recently received unofficial notification from NIH that funds have been approved for the support of the Data Services Research Laboratory in the center grant renewal effective February 1, 1977. Approval is for one year in the first instance with support for a further two years subject to satisfactory administrative arrangements.

IV.B.1.c AUTOMATIC LV MODELING

Automatic Radiographic Image Analysis by LV Modeling

Donald C. Harrison, Professor of Medicine
Edwin L. Alderman, Assistant Professor of Medicine
Lynn Quam,Ph.D., Research Associate in Computer Science

Stanford University

A proposal to carry out this research has been submitted to the NIH. Medical applications of computer image processing was part of the original collaborative research goals of SUMEX. This has been supported as a pilot project to facilitate the development of independent grant support.

The proposal is to use the facilities of SUMEX-Aim to develop a mini-computer system for the automatic analysis of left ventricular angiography in a clinical cardiac catheterization laboratory setting. This system will be designed to 1) provide frame by frame quantitative volume measurements 2) analyze wall motion abnormalities and 3) generate new information about left ventricular function. In conjunction with the SUMEX systems staff, Dr. Lynn Quam has done the initial development work on an interactive graphics and image display system as summarized below.

SUMMARY:

A general purpose hardware and software system for interactive graphics and grey-level image display has been developed on the SUMEX Tenex system, using a Tektronix 611 storage scope controlled by a PDP-11/10 processor. The system is capable of producing limited displays dynamically using the non-storage mode of the 611, whereas complex displays require the use of storage mode or photography.

A general purpose graphics package has been developed, which is essentially compatible with the graphics software at the Stanford A-I Lab. Consequently, with minor revisions, many of the graphics programs written at the A-I lab can be used at SUMEX.

Many of the image processing algorithms originally developed at the A-I lab by L. H. Quam have been revised to run in the Tenex environment.

The combined effect of the graphics and image display hardware and software is the capability for SUMEX users to perform a wide variety of image enhancement operations on grey-level images, and to display both line drawing graphics and grey-level images.

PURPOSE:

The primary purpose for developing the graphics and image display system was to support the needs of an NHLI proposal in the division of Cardiology. The proposed research was to develop algorithms to automate the procedure for outlining ventricular margins in angiograms, for the purpose of cardiac dynamic performance evaluation. The images are obtained by passing x-rays thru the patient who has a catheter placed in the heart. The x-ray target is viewed by both a cine film camera and a vidicon. The vidicon output is both viewed directly, and recorded on a video disc. Several cardiac cycles are recorded on the disc, then a radio-opaque dye is injected into the heart using the catheter, and several (at least 3) more cycles are recorded. This procedure produces about 150 images which must be analyzed.

In the normal clinical operation, a technician manually traces the ventricular margins using a light pen which is connected to a mini-computer which computes the desired performance measurements and produces hard copy output. The manual tracing is quite tedious and slow.

The primary difficulty with automating ventricular margin outlining is that during part of the cardiac cycle the margin is of very low contrast (poor signal to noise ratio), making it impossible to detect without taking adjacent (in time) images into consideration. In order to develop techniques for automatic margin definition, it was necessary to have hardware and software for image and graphics display.

HARDWARE:

The hardware consists of four component parts: a Tektronix 611 scope, a display controller, a PDP-11/10, and a PDP-10 to PDP-11 communication interface.

Tektronix 611 Scope:

A Tektronix 611 storage oscilloscope is used to generate the images. Briefly, the 611 scope has high resolution (about 100 points to the inch on a 7 by 9 inch screen), and storage and non-storage modes. Using non-storage mode increases the resolution by about a factor of 2, and allows the the display of grey-level images. Unfortunately, the 611's deflection system is too slow for direct viewing of very large images without an intolerable flicker. For large grey-level images one of two approaches must be used: photographic recording of the 611 screen, or halftone grey-level simulation using storage mode.

Display Controller:

The X, Y and Z axis signals to the 611 scope are generated by a display controller designed at SUMEX. Basically, the X and Y deflection signals are generated by two 12-bit digital to analog converters which are driven by X and Y position registers in the display controller. The Z-axis signal is controlled by a digital level which turns the 611 beam on for a time proportional to the binary number in the Z axis register.

The display controller is capable of two primary modes of operation: vector and raster. Vectors are generated as a sequence of discrete points. Vectors are specified to the hardware by the starting X, Y location, the DX, DY distance between the discrete points of the vector, and N the number of points in the vector. Grey-level rasters are generated as a sequence of discrete points (pixels) each of which can have an arbitrary intensity. To the controller, a single raster line is specified exactly the same as a vector with the addition of N 8-bit bytes of Z-axis intensity information.

The display controller is connected to a PDP-11 Unibus.

PDP-11/10:

A PDP-11/10 minicomputer is used to control the display. For images in non-storage mode, the PDP-11 dynamically refreshes the screen at about 3 microseconds per point (depending on the brightness: 3 microseconds is the minimum time). For halftone grey-level simulation, the PDP-11 executes the halftone algorithm.

PDP-10 to PDP-11 Interface:

A general purpose communication interface connects the PDP-10 to the PDP-11. This hardware consists of two 32-bit registers, one for each direction of data transfer, 2 status registers, and 2 control registers. Using this interface, data can be transferred between the PDP-10 and the PDP-11 at about 20 microseconds per word data rates (potentially).

SOFTWARE:

The software to to utilize the display hardware consists of many modules some of which execute on the PDP-10 and others on the PDP-11.

Communication Module:

Communication between the PDP-10 and the PDP-11 is accomplished by transferring blocks of data thru the communication interface which is controlled by programs running in each machine. The basic operations are:

a. Load a program in the PDP-11
b. Send a block of data to the PDP-11
c. Get a block of data from the PDP-11
d. Start a program running in the PDP-11
e. Stop the program running in the PDP-11
... and a few other operations

PDP-11 Display Module:

The display module interprets blocks of data sent thru the communication interface as commands to the display. The basic display commands are:

a. move the beam to position X,Y
b. draw a line consisting of N points, incrementing the beam position by DX,DY between each point.
c. generate a grey-level raster
d. generate a half tone raster
e. set beam brightness
f. display a string of text
g. display subroutine call
h. display subroutine return

From these primitive commands all higher level display functions are built.

PDP-10 Display Module:

The PDP-10 display module interprets SAIL procedure calls and produces blocks of data to send to the PDP-11 display module. In addition to the primitives listed above, many higher level display functions are implemented:

a. display a circle
b. display an arc of a circle
c. plot a graph of the data in a array: labelling the axes

PDP-10 Image Processing Functions:

Many of the image processing functions developed at the Stanford Artificial Intelligence Laboratory have been modified to run under Tenex. The following is a partial list:

a. Input an image from a disk file
b. Output an image to a disk file
c. Input a window of an image from a disk file
d. Display an image on the 611 scope
e. Enhance the contrast (stretch) of the image
f. Rotate the image 90 degrees clockwise
g. High-pass filter the image
h. Low-pass filter the image
i. Display the histogram of the image
j. Expand the image
k. Remove "noise" from the image (local sigma test)
l. Difference two images

IV.B.1.d INFORMATION PROCESSING PSYCHOLOGY PROJECT

INFORMATION PROCESSING PSYCHOLOGY

Prof. E. Feigenbaum (Computer Science)
and Prof. H. Cohen (U. C. San Diego)

May 1976 Report

Information Processing Psychology is concerned with the construction of models of human cognition, using the methodologies of computer simulation and artificial intelligence. The attempt is to give a precise characterization of the human information processes and information structures that underly human problem solving, learning, and perceptual behavior. Over the past two decades, research in this scientific area has produced computer models of behavior in puzzle-solving, game-playing, and theorem-proving tasks; rote learning laboratory tasks; linguistic understanding and long-term memory tasks; pattern extrapolation tasks, e.g., as are found in intelligence tests; children's seriation tasks; concept attainment tasks; visual scene understanding tasks; tasks involving mental imagery; and many others. A type of human cognitive/perceptual activity that has not been much studied is the behavior associated with the production of works of art. In the past, neither graphical/visual art-making nor musical composition has been studied in depth.

The particular project described below has sought to bring under examination one of the least well-defined areas of higher intellectual functioning -- the activities of art-making performance -- and to develop a computer model (i.e., information processing model) capable of verifying the plausibility of a number of hypotheses concerning such activities. We have addressed the subset of art-making behavior which is concerned with the production of freehand drawings, and in particular drawings which might be characterized by their imagistic richness as opposed to formal complexity.

The computer model has followed the format used in many A.I. programs: a production system in which an explicit body of knowledge is encoded as a set of rules linking the recognition of complex prior program behavior (in the making of the drawing) and current states within the drawing itself, to the exercise of appropriate subsequent rules, which in turn move the drawing into new states. The model is to be regarded as an expert or specialist, in the sense that the encoded knowledge is specifically concerned with the mechanics of image-building and does not encompass any other aspect of the world.

Since much of what we understand by "meaning" in images -- as elsewhere -- clearly involves world knowledge, there may seem to be something anomalous in a program without world knowledge designed to generate imagistically rich drawings. However, our belief has been that a large part of "meaning" is signalled by the image-structure itself, and that this is related more to the nature of underlying perceptual processes than to any particular stored perception of the world. There should be a set of pre-acculturated behavioral patterns of so fundamental a kind that their very exercise would persuade the viewer that some "meaning" was intended.

Following from this position, our selection of appropriate production rules in the production system has tended to stress a number of low level perceptual activities. Early versions of the model were able to differentiate figure from ground, closed forms from open forms, inside from outside; and also to perform tasks -- like generating a path from one point to another under certain constraints -- in feedback mode, which required a continually updated model of the state of the drawing under construction.

More recently, the model has been given enough knowledge of the mechanics of representation to permit it to manipulate the emerging drawing more fully. Thus, it knows that a closed form may function as a delineated area upon which other markings may be made; or whose flatness may be stressed by cross-hatching; or that the form may "stand for" a solid object which may be shaded or cast shadows.

The protocols referred to above are families of behavioral rules which are distributed throughout the system and become enmeshed into complex structures. For example, one aspect of the model's awareness of figure-ground relationships is a set of avoidance protocols, which prevent the invasion of existing elements in the drawing. Which of the set will be invoked will depend upon both what is being done -- in terms of currently "open" protocols -- and what is being avoided.

The major protocols currently available to the model may be summarized as follows:

closure: forms may be closed by preplanning or, at a later stage, as suggested by the state of the drawing. Reinforced by hatching, shading, marking (recursive repetition, see below), piercing, accretion.

placement: the model is able to select unused areas of the drawing of a shape and size appropriate to its current plan; its subsequent behavior is then determined in large part by the precise consideration of its environs. The model has no aesthetic criteria or compositional strategies beyond providing itself with adequate space.

avoidance: may result in the discontinuation or the modification of the current plan, with or without the development of an alternative plan; or in an attempt to circumvent the obstructing form.

repetition: in the "placement" area of the production system, this would result in similar sub-histories being repeated, subject to local conditions, in other parts of the drawing. In other conditions it will result in a recursive use of closed forms as fields upon which other closed forms may be made; in multiple division or extension of an area; in zigzags or groups of parallel lines, or in concentricity.

Long term plans include the provision of simple "world knowledge" to the problem, in order to investigate plausible specialist/non-specialist interactions in the drawing process as a source of imagistic richness. We have done some recent experimentation with people, designed to isolate and examine the protocols actually employed by a group of drawing students in a visual arts class at U.C., San Diego. The results of these experiments are now undergoing statistical analysis, and it is anticipated that much useful material will be available for the next stage of program development.

The program described above was developed in SAIL on the SUMEX facility, partly during the period when Professor Harold Cohen, of the Visual Arts Department of U.C., San Diego, was on leave at Stanford University, and partly upon his return to his campus. He has assumed the Directorship of a new Project for Art/Science Studies at UCSD, and has by gifts and grants procured for the Center a PDP/11-type facility capable of supporting the research described above on the modeling of art-making behavior. The innovative work of this SUMEX pilot project will therefore be "spun off" to a fruitful environment at UCSD. As a SUMEX activity, this particular research has effectively terminated.

<u>Bibliographic References</u>

1. Cohen, H. "Steps toward a Theory of Meaning", invited paper, International Sculpture Conference, U. of Kansas, March, 1974

2. Cohen, H. "On Tools and People, Including Computers and Artists", invited paper, Conference on Computers in Art, Purdue Univ., 1975.

3. Cohen, H. "The Simulation of Perception: Problems in Generating Drawings by Machine", invited paper AAAS Annual Meeting, 1972.

4. Cohen, H. "On Purpose", <<Studio International>>, January, 1974.

5. Cohen, H. "Parallel to Perception", <<Proceedings of the Edinburgh Conference on Art and Computing>>, 1973

IV.B.1.e AIM RESEARCH - UNIVERSITY OF ROCHESTER

AIM Research - University of Rochester

Drs. Feldman, Rovner, and Low
Rochester University

(Grant NSF DCR74-24203, 2 years, $149,956 total and
Sloan Fdn. 74-12-5, 3 years, $120,000 last year)

SUMEX facilities are being used at the University of Rochester by a group of about 10 second-year medical students under the direction of Charles Odoroff, Biostatistics. Their work is either an optional part of a course in biostatistics and epidemiology, or an individual project. They have studied some of the documentation of the MYCIN system, and have experimented with using it both on canned case histories and on cases from the files of microbiologists at the U. of R. Medical School. At least one evaluative paper has been written. It is planned to use the CASNET system in the same way.

There is continuing system development work, especially for the SAIL language system.